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The Muirkirk Mammoth: A Late Pleistocene woolly mammoth (*Mammuthus primigenius*) skeleton from southern Ontario, Canada

C.R. Harington [a,*], Dick Mol [b], Johannes van der Plicht [c,d]

[a] Canadian Museum of Nature (Paleobiology), Ottawa, Ontario, Canada K1P 6P4
[b] Natural History Museum, P.O. Box 23452, 3001 KL Rotterdam, The Netherlands
[c] Centre for Isotope Research, Radiocarbon Laboratory, University of Groningen, Nijenborg 4, 9747AG Groningen, The Netherlands
[d] Faculty of Archaeology, Leiden University, P.O. Box 9515, 2300 RA Leiden, The Netherlands

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ABSTRACT

The Muirkirk Mammoth, found in 1895 2.4 km northeast of the village of Muirkirk in southern Ontario, is the most complete woolly mammoth (*Mammuthus primigenius*) skeleton known from Canada. Approximate tusk measurements and extreme wear on the sixth molars indicate it is best referred to an old male. Its geological age was controversial because the first two Holocene bone collagen radiocarbon dates were derived evidently from contaminated samples. Three new radiocarbon dates on carefully selected bone and ivory are close, averaging 12,190 BP, and indicate that this mammoth died before the close of the Wisconsinan glaciation and near the time of extinction of woolly mammoths in this part of North America. Its assignment to regional pollen subzone 1b suggests that, like the Rostock Mammoth of similar age from southern Ontario, it lived in a tundra woodland environment. The Highgate Mastodon (*Mammut americanum*) and giant beaver (*Castoroides ohioensis*) found 4 km away and also assigned to pollen subzone 1b suggests that some spruce wetlands characterised the tundra woodland environment, and that perhaps woolly mammoths and American mastodons lived almost side by side in southern Ontario about12,000 radiocarbon years or 14,000 calendar years ago. The Muirkirk Mammoth is discussed in relation to the dispersal history of woolly mammoths.

1. Introduction

A great deal is known about the appearance of woolly mammoths as a result of the discovery of several well-preserved carcasses in frozen ground in Siberia. Further information has come from the study of many detailed carvings, engravings and murals by Paleolithic artists from European caves – some dating back 30,000 years or more.

Woolly mammoths grew to the size of Asiatic elephants (*Elephas maximus*) – about 3 m high at the shoulders (weighing about 6 tons), and had similar teeth. The similarity in size of woolly mammoths and Asiatic elephants suggests that they had similar age-spans – up to about 60 years (Lister and Bahn, 2007, p. 174). Cheek teeth were massive, comprising a large series of tightly-appressed enamel plates filled with softer dentine and surrounded by cementum, that anchored the teeth in the jaws. As the teeth wore, the enamel ridges stood out and were excellent grinding mills for the relatively tough, dry grasses on which these animals habitually fed. As in modern elephants, during a complete lifetime 6 M-like teeth developed in each side of each jaw, making 24 in all. Successive teeth grew forward from the back of the jaw replacing earlier, smaller teeth as they wore, moved forward and dropped out.

Woolly mammoth coats were similar to those of living tundra muskoxen (*Ovibos moschatus*) and consisted of long (up to 90 cm), dark guard hairs and fine underwool underlain by dark-grey skin and an insulating fat layer, in some cases up to 90 mm thick.

Other features characteristic of the species (Fig. 1) were: a high, peaked head that appears knob-like in many cave depictions; a high hump resulting from the long neural spines of the neck vertebrae, possibly accentuated by fat deposits and thick hair; a trunk shorter than those of living Asiatic or African elephants (*Loxodonta africana*) and large (up to 4.2 m long), elaborately curved tusks – particularly in old males. Tusks of adult females are smaller than those of males.

Woolly mammoths were first recorded in northeastern Siberia dating to approximately 700,000 years ago, being derived from the massive steppe mammoths (*Mammuthus trogontherii*). As time progressed, several changes occurred in the cheek teeth of woolly mammoths. The series of enamel plates became more numerous

* Corresponding author.
E-mail address: dharington@mus-nature.ca (C.R. Harington).

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Abbreviations

5	Fifth (second last molar). Superscript indicates an upper molar and subscript a lower molar
6	Sixth (last molar)
+	Original unworn or undamaged bone or tooth measurement would have been larger
AMS	Accelerator Mass Spectrometry technique of Radiocarbon dating
APDBJ	Anteroposterior diameter of ball joint
APDMR	Anteroposterior Diameter of Medial Rotule
BP	Radiocarbon years Before Present (about 1950)
CMN	Canadian Museum of Nature, Ottawa
DD	Distal Depth
DW	Distal Width
ET	Enamel Thickness
Ft	Feet
GL	Greatest Length
GSC	Geological Survey of Canada, Ottawa
Kg	Kilogramme(s)
Km	Kilometre(s)
L	Left
Lb	Pound(s)
LF	Lamellar Frequency (number of lamellae in 100 mm span)
LGM	Last Glacial Maximum (about 20,000 BP)
LRP	Length of Radius Preserved
LUP	Length of Ulna Preserved
M	Metre(s)
M	Molar
Ma	Million years ago
MADC	Maximum Anteroposterior Depth of Centrum
MAPD	Maximum Anteroposterior Depth
MBPAS	Maximum Breadth of Proximal Articular Surface
MCS	Minimum Circumference of Shaft
MD	Maximum Depth
MDABA	Minimum Diameter Across Base of Acetabulum
MH	Maximum Height
MHC	Maximum Height of Centrum
MHNC	Maximum Height of Neural Canal
ML	Maximum Length
MLWS	Maximum Length of Worn Surface
Mm	Millimetre(s)
MSD	Midshaft Depth
MSW	Midshaft Width
MSWU	Minimum Shaft Width of Ulna
MW	Maximum Width
MWAS	Maximum Width of Articular Surface
MWC	Maximum Width of Centrum
MWDE	Maximum Width of Distal End (at epiphyseal suture)
MWNC	Maximum Width of Neural Canal
MWPER	Maximum Width of Proximal End of Radius
MWRM	Maximum Width of Right Mandible
MWRS	Minimum Width of Radius Shaft
N	Number of enamel plates preserved
PD	Proximal Depth
PW	Proximal Width
R	Right
TL	Total Length

and crowded, and the enamel plates became thinner. Also, the tusks became more curved and body-size decreased. Such changes were advantageous in chewing tougher, more abrasive tundra or steppe-like vegetation, and probably the decrease in body-size (accompanied by reduction of extremities such as ears, tail and trunk) and development of a thicker pelt enabled these mammoths to survive under increasingly cold conditions.

Remains of this species, especially the durable molar teeth and tusks, have been found mainly in the northern parts of Eurasia and North America. Probably originating in Siberia, woolly mammoths spread westward to the British Isles and Spain, and eastward via the Bering Isthmus to tundra-like or steppe-like regions of North America.

During the last (Wisconsinan) glaciation, when most of Canada was covered by ice, the species was isolated in refuges north and south of the ice sheets, where most died out between 12,000 and 10,000 years ago (Harington, 1978, 1995, 2003; Kurtén and Anderson, 1980; Lister and Bahn, 2007; Mol and van Essen, 1992).

The purpose of this paper is to provide background information on, describe in detail for the first time, and illustrate the skeleton of the Muirkirk Mammoth from southern Ontario, and to resolve the controversy over unusually late (Early Holocene) radiocarbon dates on bone and tusk from the specimen. In addition, it presents an idea of the environment the mammoth occupied when it died, and provides a perspective on the Muirkirk Mammoth in relation to the dispersal history of the species.

2. The find, its geographic and stratigraphic setting

Most of a skeleton of a mammoth was found and excavated by a farmer, Charles Fletcher, on his farm about 1.5 miles (2.4 km) northeast of the village of Muirkirk (42°31'N, 81°46'W) in 1895 (Fig. 2). The bones were discovered in a field that had a short time before been burnt over and was being ploughed for the first time. A surface layer of peat about 2–3 feet (0.6–0.9 m) deep had been removed by the fire, leaving exposed a brownish-grey clay containing small pebbles, known as "Erie clay" in this region. The bones were found just beneath the clay surface, being horizontally embedded in the clay and scattered over 2 rods square (about 5 m^2). The ploughshare first struck and broke one of the tusks that proved to be 8.5 feet (2.6 m) long. The second tusk, found nearby, was about 10 feet (3 m) long. The rest of the skeleton, found in the immediate vicinity, consisted of: most of the limb bones; a nearly complete lower jaw with teeth in place; parts of the upper jaws with teeth; fragments of the upper part of the cranium; some ribs; a few fragmentary vertebrae; and several foot bones. The two hind legs were almost complete, but some of the foot bones were not recovered. L.M. Lambe (1898), then paleontologist with the Geological Survey of Canada (GSC), visited the site in September 1897, and purchased the remains of this skeleton for the GSC (Lambe, 1898; Dawson, 1901; Dawson and Jenkins, 2007).

3. Radiocarbon age and paleoenvironment

The first radiocarbon date of 8310 ± 200 BP (Beta-17869) (calibrated: 7540–7080 BC – see intcal 09 plot, Fig. 3, where cal BP is in calendar years relative to 1950; thus cal BP = 1950 + BC) was obtained on a sample of bone from the distal end of the right ulna, that required careful pretreatment because "rootlets are seen in spongy bone parts of sample". Because of that comment and the unusual lateness of the date, it needed to be checked.

In an attempt to overcome the possible problem of contamination, a second sample (interior tusk) was submitted for dating. It

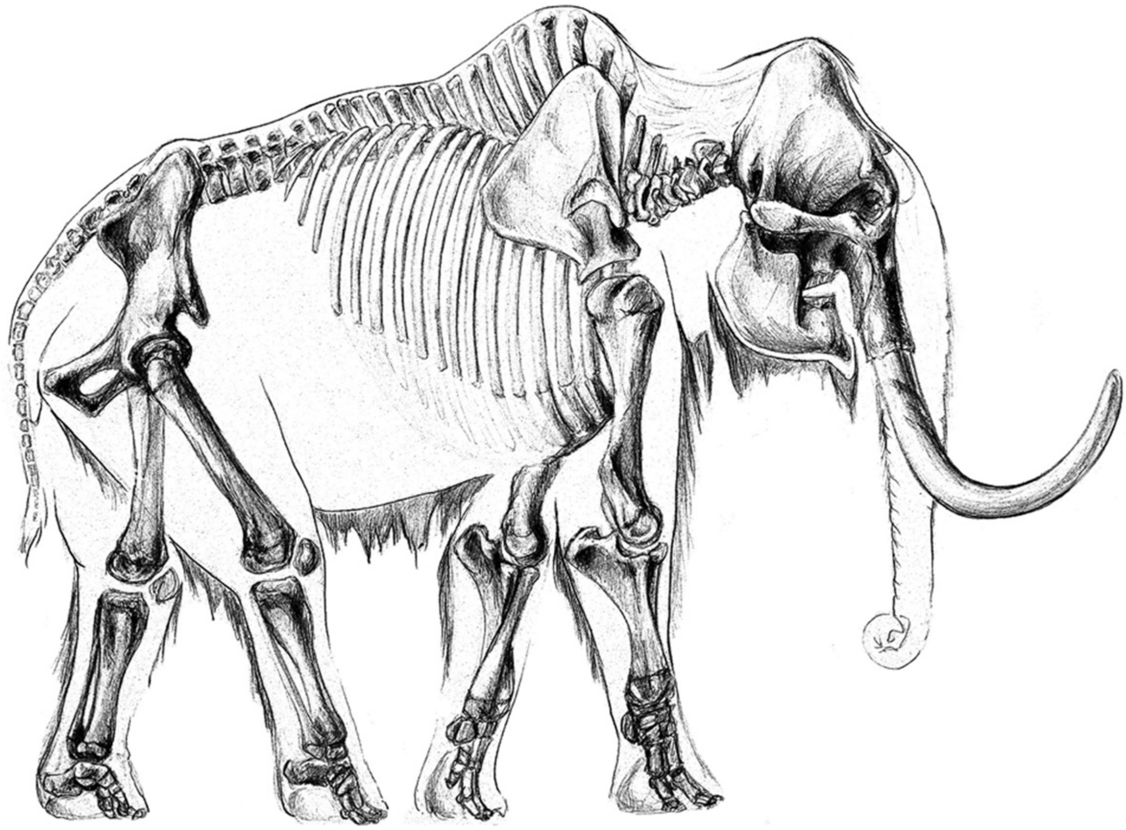

Fig. 1. Right side view of woolly mammoth (*Mammuthus primigenius*). Anatomical study showing skeletal structure, with an outline of soft tissues. Illustration from Mol and van Essen 1992.

yielded an even younger radiocarbon age of 6440 ± 60 BP (Beta-115209), also suggesting contamination (Harington, 2003; Radiocarbon Date Table).

McAndrews and Jackson (1988) rejected the Muirkirk Mammoth date of 8310 ± 200 BP "as being too young because the dated bone was contaminated with rootlets (J. Stipp, Beta Analytic, Inc., personal communication to McAndrews, 1986); the associated pollen assemblage is zone 1". McAndrews and Jackson (1988, p. 167) suggested that because the Muirkirk Mammoth is from the Ridgetown Island Moraine it probably dates after 12,700 BP.

Comparison of the Muirkirk Mammoth with the Rostock Mammoth (*Mammuthus* sp.) – the only other radiocarbon-dated mammoth specimen from Ontario – is worth mentioning (McAndrews and Jackson, 1988). That mammoth specimen (ROM 29753) consisted of a skull fragment with LM^5 (= "LM^2")in place, a cervical vertebra, a scapula fragment and part of a limb bone found on the cultivated surface of a peaty swale [depression] some 230 km northeast of Muirkirk. Collagen from the scapula was dated at 4290 ± 120 BP (WAT-945), but tusk collagen yielded a date of 10,790 ± 150 BP (WAT-999) (Pilny et al., 1987). Pollen analysis of sediment from cavities in the Rostock Mammoth skull indicated that the skull was deposited near the end of pollen subzone 1b, as jack pine (*Pinus banksiana*) began to succeed spruce (*Picea* sp.). Because the younger date (4290 ± 120 BP) from the scapula was on porous bone subject to contamination by modern rootlets, McAndrews and Jackson (1988) "reject it and accept the date on the less porous tusk, but more importantly the older date accords with the age of the spruce zone sediment". Thus, similar problems were encountered in radiocarbon dating the Muirkirk and Rostock mammoth remains. However, both were best assigned to pollen subzone 1b (pond marl underlying the peat of zone 2 in the case of the Rostock Mammoth) with pollen indicating a tundra woodland that was more dense in 1b than 1a (McAndrews and Jackson, 1988).

This paper reports on three new radiocarbon dates on freshly-selected, clean samples from the Muirkirk Mammoth. They were measured at the Groningen ^{14}C laboratory; two samples were measured by the conventional method (laboratory code GrN), and one by AMS (laboratory code GrA). Finally, this process now yields the first reliable information on the geological age of the Muirkirk Mammoth: 12,130 ± 80 BP (GrA-22177) on bone (sample CM-DM-60) from the interior of the left cuboid (CMN 6747 www); 12,180 ± 70 BP (GrN-28020) on a fragment of cranial bone (sample CM-DM-61A); and 12,250 ± 70 BP (GrN-28022) on tusk ivory (sample CM-DM-61B). These three dates overlap within measurement error. The weighted mean of the three dates is 12,190 ± 40 BP, which calibrates to 12,140–12,060 BC, indicating that the most reliable geological age is toward the close of the Wisconsinan glaciation (about 10,000 BP). This age is in accord with McAndrews and Jackson's (1988, p. 167) suggestion that the Muirkirk Mammoth probably dates after 12,700 BP.

4. Descriptive paleontology

Order Proboscidea Illiger, 1811
Family Elephantidae Gray, 1821
Genus *Mammuthus* Burnett, 1830
Mammuthus primigenius (Blumenbach, 1799)

According to the high degree of fusion of the bones and heavy wear on the sixth molars of the Muirkirk Mammoth (CMN 6747), it represents an old individual. [As in living elephants, the sixth molars replace the fifth molars at about 30 years of age (Lister and Bahn, 2007, p. 174, p. 174)]. Also, the maximum length of 595 mm

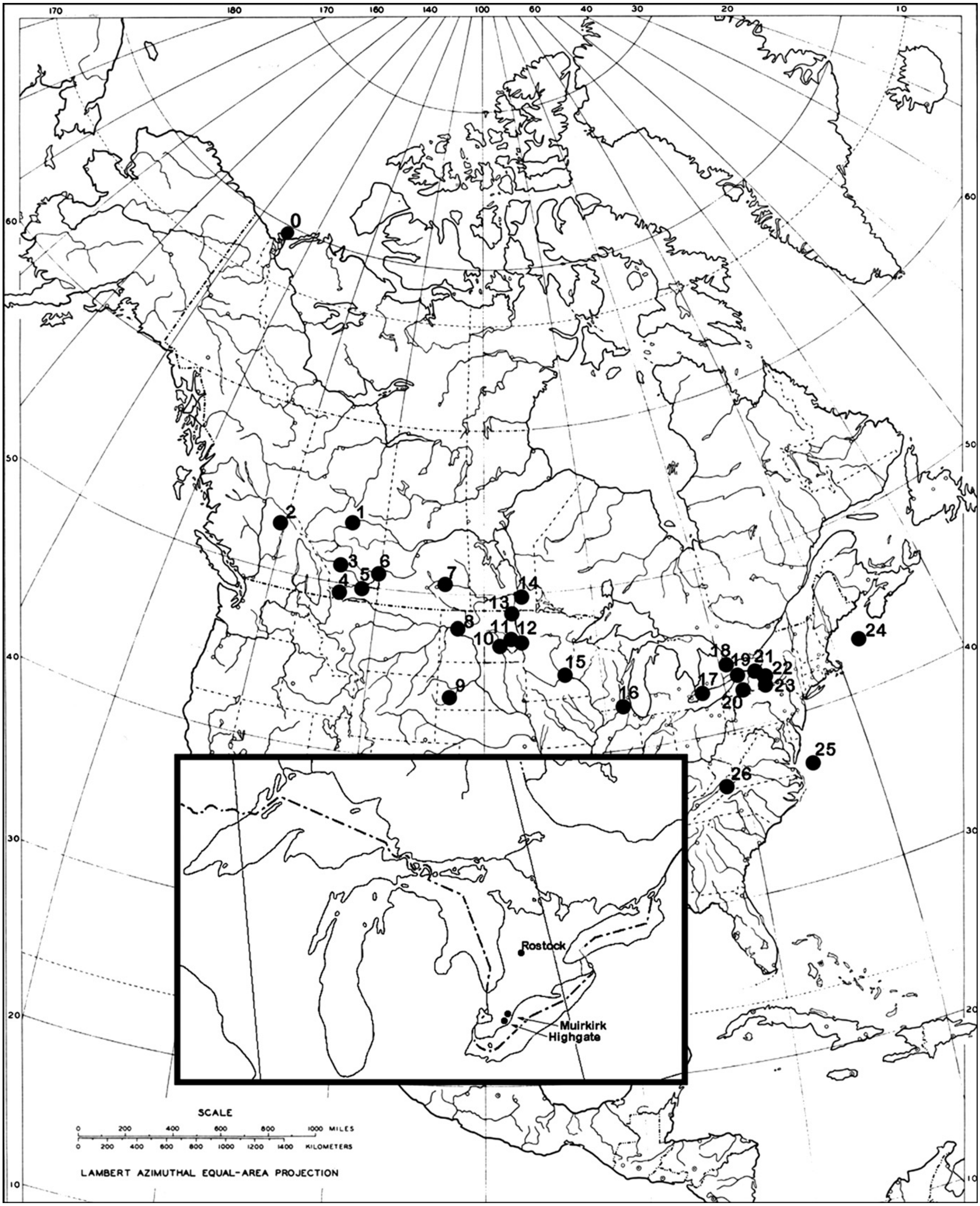

Fig. 2. Map (inset) showing the Muirkirk Mammoth locality in relation to those of the Rostock Mammoth and Highgate Mastodon, and to some other woolly mammoth sites south of the Wisconsinan ice sheets or in the ice-free corridor between the Laurentide and Cordilleran ice. Legend: 0, Kendall Island, Northwest Territories (included because, like the Muirkirk Mammoth the radiocarbon-dated specimen was anomalously late); 1, Edmonton, Alberta (mid-Wisconsinan); 2, Grouse Creek, British Columbia; 3, Chestermere Lake near Calgary, Alberta; 4, Wally's Beach (tracks), near Cardston, Alberta; 5, Medicine Hat, Alberta; 6, Empress, Alberta; 7, Fort Qu'Appelle, Saskatchewan; 8, near Watford City, North Dakota; 9, Hot Springs, South Dakota; 10, near Millarton, North Dakota; 11, near Absaraka, North Dakota; 12, near Embden, North Dakota; 13, Walhalla, North Dakota; 14, near Dufresne, Manitoba; 15, Minneapolis, Minnesota; 16, Hebior, Wisconsin (found with stone artifacts); 17, Muirkirk, Ontario; 18, Toronto area, Ontario; 19, Lewiston, New York, 20, Randolph, New York; 21, Clyde and Savannah, New York; 22, Homer, New York; 23, Salina, New York; 24, Georges Bank, Nova Scotia (northeastern corner); 25, Atlantic continental shelf off Cape Henry, Virginia; 26, Saltville, Virginia (Hay, 1923, 1924; Whitmore et al., 1967; Harington, 1977; Harington and Shackleton, 1978; McDonald and Bartlett, 1983; Harington and Ashworth, 1986; Cooke et al., 1993; Agenbroad et al., 1994; Burns and Young, 1994; Burns, 1996; McNeil et al., 2007).

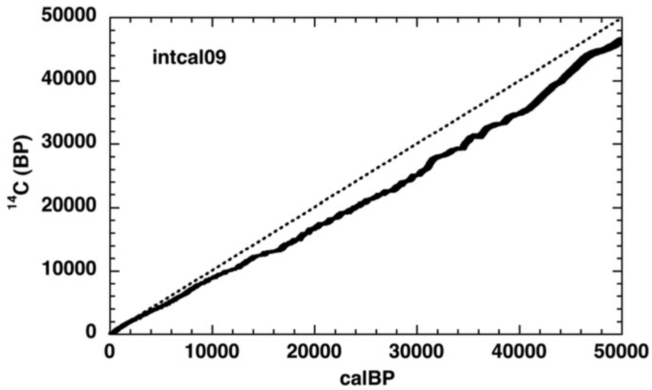

Fig. 3. Plot intcal 09 for conversion of Radiocarbon years (BP) to calendar years (cal BP) (Reimer et al., 2009).

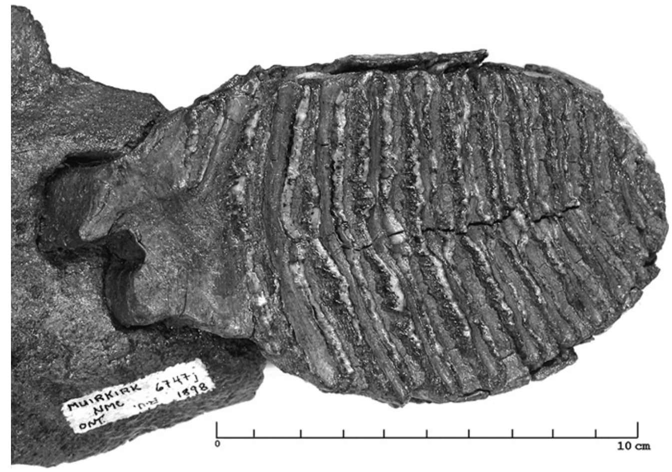

Fig. 4. Occlusal view of RM^6 (anterior to right). Note heavy wear to near roots denoting old age.

and maximum width of proximal end 197 mm of the tibiae indicate that the Muirkirk Mammoth died just beyond the oldest age category (V) of woolly mammoths from Sevsk, Russia – over 40 years (Maschenko, 2002, Figure 38d). Approximate measurements of the tusks (2.6–3 m long) suggest that it is best assigned to a male [e.g. "More typical is a length of 8–9 ft (2.4–2.7 m) and a weight of about 100 lb (45 kg). These figures apply to males…. Typical female tusks were about 5–6 ft (1.5–1.8 m) long…" (Lister and Bahn, 2007, p. 94, p. 94)]. Bones are generally well-preserved, and are light brown in colour showing the presence of iron in the surrounding groundwater. A lamellar frequency (LF) of 10 and an enamel thickness (ET) of about 2 on a well worn sixth molar indicates that this mammoth is best referred to a woolly mammoth (*M. primigenius*) – one of several identified from the southern refugium (Harington and Ashworth, 1986, Fig. 3), as opposed to the Eastern Beringian refugium that existed in northwestern North America (Harington, 2005). The apparent "primitiveness" of the sixth molars (e.g. relatively low lamellar frequency and high enamel thickness; but see extremes of LF and ET for Late Pleistocene *M. primigenius* in Ferretti, 2003) may be expected in such well worn-teeth (Agenbroad et al., 1994, p. 274). Careful examination of the bones shows no signs of damage by accident during life, or alteration by humans, carnivores, or scavengers, so the Muirkirk Mammoth may have died by other causes, possibly related to age and/or becoming bogged down in moist clay. It is worth emphasising that the bones were disturbed from their articulated position and badly damaged by cultivation.

4.1. Specimens

Cranium – Anterior part of left zygomatic arch (CMN 6747a); right temporal condyle (b); fragment near tusk socket ?(d); part of auditory capsule (f); fragment near tusk socket (h); c, e, and g also appear to be cranial fragments; upper left sixth molar (LM^6) (i) with heavily-worn occlusal surface (ML 153.0; MLWS 130.0; MW 76.7; N 13.0; LF 10.0 near roots); ET 2.0 (near roots); upper right sixth molar (RM^6; Fig. 4) with part of anterior socket (j) (ML 162.3; MLWS 145.2; MW 83.0; N 12.0$^+$; LF 10.5 near roots); ET 2.1 (near roots). Tusk fragments (m, n, o, p. q).

Mandible – Lower right sixth molar (RM$_6$; Fig. 5) (k) (ML 172.7; MW 73.1; N 12.0; LF 8.0 (near roots); ET 2.5; MWRM 161.0 – anteromedial part of right socket lacking; lower left sixth molar (LM$_6$; Fig. 6) (k) – occlusal surface well worn and only M$_6$s are left in mandible (ML 168.2; MW 72.7; N 12.0; LF 8.0 (near roots); ET 2.4.

Vertebrae – Cervical vertebra (r), lacking right lower quarter of centrum and most of neural spine (MWNC 86.8; APDC 40.8); cervical vertebra fragment (y); thoracic vertebra [approximately a third thoracic (s) with bone surrounding the neural canal (MW 76.7; MH 74.0) with just the top of the centrum and complete neural spine (TL 306.4)]; thoracic vertebra (approximately distal quarter, lacking the neural spine) (t); proximal half of neural spine (u); neural spine lacking tip (v); bone surrounding the neural canal with about one-third of centrum and complete neural spine (x) (MWNC 59.9; MHNC 41.5); lumbar vertebra lacking parts of anterior and posterior epiphyseal plates of centrum and nearly the distal three-quarters of the neural spine (z) (MWNC 72.0; MHNC 63.9; MHC 104.5; MWC 112.4; APMDC 65.8).

Ribs – Rib fragments (24 including aa-rr, tt-yy). Of these, cc and ww are most complete, and gg has the spatulate shape of the blade of a first rib.

Scapula – Left scapula (zz) (40 mm of the proximal end is preserved, but badly damaged).

Humeri – Right humerus (aaa) (GL about 870; MSW 110.3; MCS 349.0) – the distal end is damaged so no measurements are available there. Left humerus (bbb). Most of the medial side of the shaft is preserved (nearly 360 mm above the supracondyloid ridge) (APDMR 150.6). The posterior part of the distal end is damaged.

Radioulna – Right radioulna (ccc; Fig. 7) partly fused, distal end of radius lacking, distal end of ulna is damaged, and most of olecranon process is missing (MBPAS 201.7; MSWU 87.9; LUP about 600; MWPER 101.0; MWRS 38.8; LRP about 420). Left radioulna (dddd) – proximal articular surface preserved, but too fragmentary to measure.

Forefoot – Left pisiform (ddd) (TL 129.4; ML 129.4; PW 41.8; PD 56.3; MW 28.9; MD 49.1; DW 38.4; DD 56.5); right cuneiform (eee) (MAPD 110.3; MH 61.3; MW about 118.6); left cuneiform (iiii) (MH 71.6; PW 29.1; PD 49.8; MSW 260.0; MSD 51.7; DW 28.5; DD 49.7); right lunar (fff) – damaged (MAPD 116.1; MW 103.0$^+$; MD 66.9$^+$); right unciform (jjj) (MD 109.8; MW 93.5; MH 101.4); right metacarpal IV (zzz) damaged (TL 159.6; ML 164.0; PW 63.9; PD 74.3; MSW 61.5; MSD 42.5; DW 77.0; DD 74.6); left metacarpal II (yyy) (TL 163.5; ML 176.0; PW 96.0; MSW 59.8; MSD 42.2; DW 79.8; DD 76.3); left metacarpal V (cccc) (TL 123.1; ML 146.1$^+$; PD 89.4; MSW 57.3; MSD 77.9; DW 68.4; DD 42.2).

Pelvis – Right innominate fragment (anterior portion of ilium, part of acetabulum and shaft of ischium (iii) (MDABA 169.8). Left innominate fragment (kkk-lll) (MDABA 159.2$^+$).

Femora – Left femur with proximal end (tip and ball joint) damaged and proximomedial region broken away and mediodistal portion of shaft restored (mmm) (ML 1 m 2 mm; APDBJ about 150; MSW 111.0; MWDE 208.0; MCS 313.0); right femur (nnn) damaged

Fig. 5. Right side view of most of mandible with RM_6 in foreground and anterior of LM_6 in background.

and greater trochanter broken away (ML 1m 10 mm; APDBJ 153.3; MSW 121.2; MCS 327.0; MWDE (across articular surface) 184.7).

Tibiae – Right tibia (ooo) with proximomedial surface damaged (ML 595.0; MSW 90.2); left tibia (ppp; Fig. 8) slightly damaged near anterodistal end (ML 588.0; MWPE 197.0; MSW 90.3; MSC 259.0; MWDE 122.7).

Fibulae – Right fibula (qqq) with tip of proximal end missing (ML 584.0 as preserved; MWDE 99.6; MCS 90.0); left fibula (qqq') lacking proximal end (ML as preserved about 540^{+}; MCS about 97.0; MWDE 104.4).

Hindfoot – Right calcaneum (rrr; Fig. 9) (MH 164.6; MAPD 117.5; MWAS 146.7); left calcaneum (sss) (MH 172.2; MAPD 118.7; MWAS 145.7); right astragalus (ttt; Fig. 8) (MAPD 116.5; MW 149.6; MH 82.8); left astragalus (uuu) (MAPD 116.5; MW 141.6^{+}; MH 83.4); right navicular (vvv) (MAPD 81.3; MW108.5; MH 39.2); left navicular (www) (MAPD 79.3; MW 114.4; MH 39.9): right cuboid (hhh) (MAPD 94.6; MW 92.0; MH 48.0); left cuboid (ggg) (MAPD 97.3; MW 102.9; MH 49.1); right metatarsal III (bbbb) (TL 132.8; ML 134.6; PW 61.4; PD 87.1; MSW 53.4; MSD 41.4; DW 71.8; DD 67.4); right metatarsal IV (aaaa) (TL 127.8; ML 129.4; PW 56.1); MSW 44.3; MSD 43.2; DW 61.8; DD 71.8); right metatarsal V (ffff) (TL 73.6; ML 75.3; PW 69.0; PD 53.0; MSW 61.5; MSD 61.8; DW 70.3); phalanges (not identifiable as forefoot or hindfoot); first phalanx (kkkk) (TL 63.4; ML 71.6; PW 60.7; PD 50.8; MSW 48.0; DW 56.8; DD 38.4); first phalanx (eeee) with articular ends damaged (TL 78.1; MSW 44.0; MSD 40.2; DD 42.2); first phalanx (jjjj) – proximal portion (PW 53.1^{+}; PD 59.3; MSD 42.0).

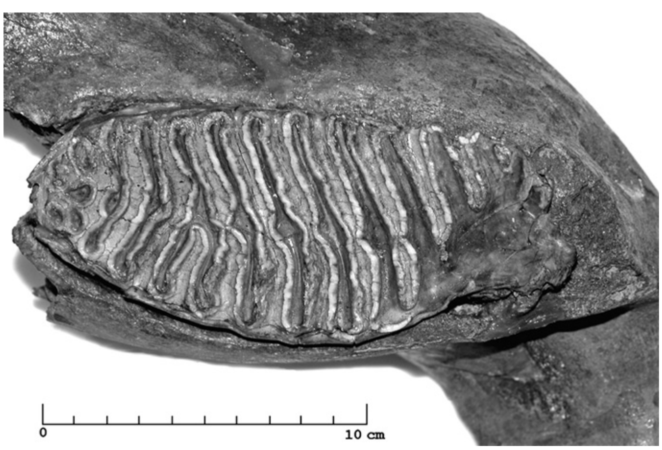

Fig. 6. Occlusal view of LM_6 (anterior to right). Note heavy wear to near roots denoting old age.

5. Discussion

It is worth discussing the Muirkirk Mammoth in relation to the known dispersal history of woolly mammoths. The species was first recorded in deposits of the Kolyma Basin, Siberia, dating to about 700,000 years ago (Lister and Bahn, 2007, p. 31), and stemmed from the massive steppe mammoth. Fully-evolved woolly mammoths were present about 400,000 years ago, appearing in Europe some 150,000 years ago (Lister and Bahn, 2007, p. 29). They spread westward via the English Isthmus (land exposed during glaciations

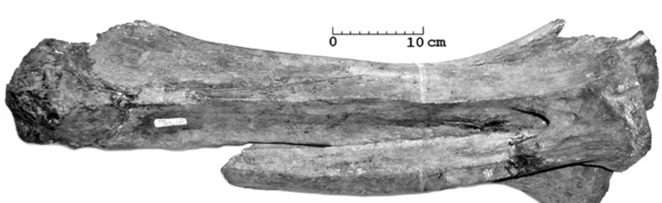

Fig. 7. Anterolateral view of right radioulna showing strong fusion of radius with ulna proximally, marking age. Proximal end of ulna and distal end of radius are missing.

Fig. 8. Anterior view of left tibia.

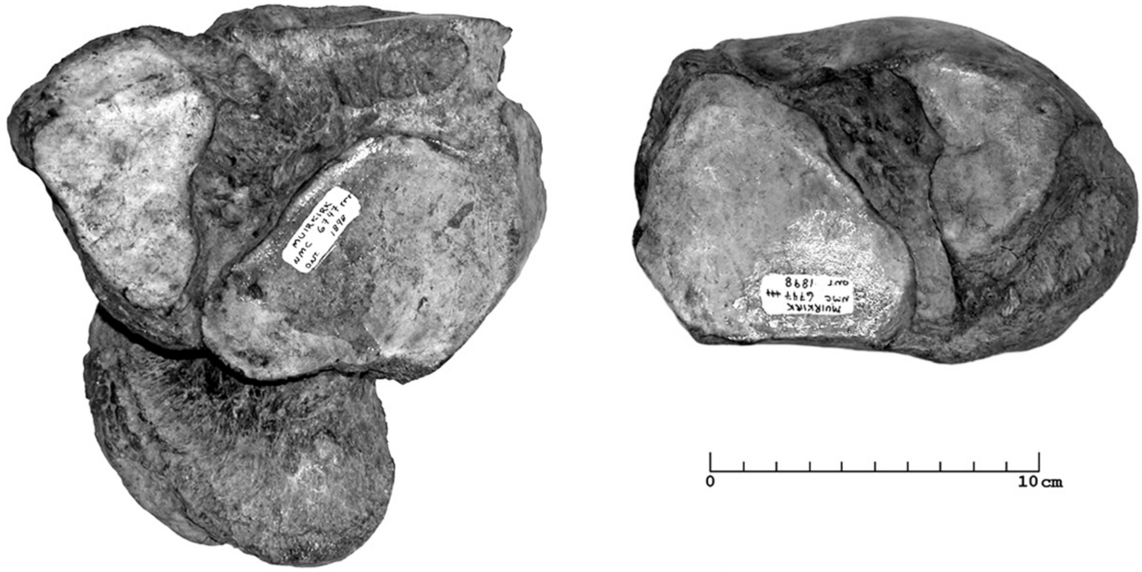

Fig. 9. Articulating facets of right calcaneum (L) and right astragalus (R).

connecting mainland Europe with Britain) to the British Isles, and eastward to northwestern North America via the Bering Isthmus (Harington, 2005), following steppe and tundra-like habitat to which they were best adapted. The migration to northwestern North America (Eastern Beringia) may have occurred about 200,000– 100,000 years ago (Lister and Bahn, 2007, p. 35; Debruyne et al., 2008, p. 35). Radiocarbon-dated woolly mammoth specimens from mainland Alaska, Yukon and Northwest Territories show that they ranged in age from >40,000 to about 14,000 BP (Harington, 2003; Radiocarbon Date Table, pp. 393–394). The radiocarbon date of 8280 ± 60 BP (Beta-115204) on a molar (ARI-8) from Kendall Island, Northwest Territories (Fig. 2, 0), like the Holocene dates on the Muirkirk Mammoth, needs to be revised. The first author has received new dates on two fragmentary woolly mammoth molars from Kendall Island. ARI-8 has been redated by AMS to 49,900 ± 3400 BP (UCIAMS-78114), so the 8280 BP Beta date must have resulted from sample contamination. The other molar fragment (ARI-7) also has yielded a mid-Wisconsinan age of 32,070 ± 370 BP (UCIAMS-78113).

Woolly mammoths had reached Edmonton, Alberta by 26,750 ± 790 BP (AECV-1102c) (Burns and Young, 1994; Burns, 1996) suggesting that they with brown bears (*Ursus arctos*) (Matheus et al., 2004) were able to penetrate the heartland of North America via an ice-free corridor during the mid-Wisconsinan. It may have been during that relatively warm phase of the last glaciation that humans, pre-adapted to hunting and butchering woolly mammoths in Eastern Beringia (Morlan, 2003; Harington and Cinq-Mars, 2008), moved south too, enabling them to hunt and butcher Columbian mammoths (*Mammuthus columbi*) at two sites on the Great Plains (Nebraska and Kansas) during the LGM about 19,000 to 18,000 BP (Holen, 2006). Columbian mammoths, may have been derived from a species like the southern mammoth (*Mammuthus meridionalis*) or primitive steppe mammoth (*M. trogontherii*) that had reached what is now California up to 1-2 Ma – a much earlier invasion of North America than that of the woolly mammoths (Lister and Bahn, 2007, p. 34).

In any case, woolly mammoths occupied tundra-like or steppe-like range south of the Wisconsinan ice sheets from southern British Columbia and Alberta eastward to the Atlantic continental shelf from southern Nova Scotia [e.g. Georges Bank about 12,300 BP (Cooke et al., 1993)] to Virginia (Fig. 2). This range roughly conforms with the "Mammoth Steppe" south of the North American ice sheets on an LGM paleovegetation map (Lister and Bahn, 2007, p. 29; Agenbroad et al., 1994, Figure 10; Harington and Ashworth, 1986, Fig. 3). The Muirkirk Mammoth lies within a cluster of woolly mammoth specimens near the eastern end of this range. It and the Rostock Mammoth evidently occupied forest tundra habitat, probably having a parkland aspect with extensive tracts of grassland required by woolly mammoths, toward the close of the Wisconsinan. Furthermore, the Highgate Mastodon (*Mammut americanum*) skeleton (found only 4 km southwest of Muirkirk), like the Muirkirk Mammoth, belongs to pollen subzone 1b dating between about 12,000 and 10,000 BP. A giant beaver (*Castoroides ohioensis*) skull found with the Highgate Mastodon, presumably indicates open spruce wetlands in that tundra woodland habitat (Harington, 2007).

About 500 km west of the Muirkirk Mammoth site, remains of several woolly mammoths have been recovered (also in clay beneath surface peat) at four sites in southeastern Wisconsin (Fenske, Mud Lake, Schaefer and Hebior). The Schaefer Mammoth most likely represents a hunted animal, while the Hebior Mammoth (about 90% complete) was hunted or found fresh by humans. At these sites, both hunting and scavenging of mammoths by pre-Clovis people has been demonstrated (Johnson, 2007). It is worth noting that the Hebior Mammoth has been radiocarbon-dated between 12,590 and 12,480 BP, so people were hunting woolly mammoths west of Muirkirk about the same time as the Muirkirk Mammoth died.

6. Conclusions

1. The Muirkirk Mammoth, the most complete Canadian woolly mammoth skeleton, discovered in 1895 and overdue for study more than 100 years later, is described here.
2. Evidently, it represents an old male that was excavated from "Erie clay" below a surface peat unit nearly 1 m thick by Charles Fletcher on his farm near Muirkirk in southern Ontario. Perhaps it became bogged down in sticky clay and died there. There are no signs on the bones of accident (e.g., naturally broken bones) or alterations by carnivores, scavengers or humans. However some of the bones were disturbed and badly damaged by ploughing.

3. Its geological age was controversial because the first two radiocarbon dates yielded Holocene ages. Evidently the bone samples were contaminated. Three new radiocarbon dates on solid, clean bone and tusk ivory are close and average about 12,000 BP (which calibrates to about 14,000 calendar years ago), indicating that the Muirkirk Mammoth died before the close of the Wisconsinan glaciation in a tundra woodland environment.
4. Like the Rostock Mammoth and Highgate Mastodon (found only 4 km away), the Muirkirk Mammoth is assigned to regional pollen subzone 1b. So, they all occupied a tundra-spruce woodland environment, with some grassland patches and wetland areas as indicated by the penecontemporaneous mastodon and giant beaver specimens from nearby Highgate.
5. Woolly mammoths may have entered North America (Eastern Beringia) from Eurasia about 200,000–100,000 years ago, reaching the heartland of North America via an ice-free corridor in what is now Alberta during the relatively warm mid-Wisconsinan interval about 27,000 BP. Perhaps humans, pre-adapted to hunting woolly mammoths in Eastern Beringia followed the same route south about that time.
6. Woolly mammoths were hunted in southeastern Wisconsin (see the Hebior site, Fig. 2, No. 16) by pre-Clovis people about 300 years before the Muirkirk Mammoth died. The Muirkirk Mammoth (about 12,000 BP) is close in geological age to other radiocarbon-dated remains of woolly mammoths from the eastern part of their range south of the Wisconsin ice sheets (e.g., Hebior, Wisconsin about 12,500 BP; Georges Bank, Nova Scotia about 12,250 BP; Saltville, Virginia about 13,500 BP) – presumably near their time of extinction in this region.
7. Woolly mammoths, with other tundra-adapted mammals [e.g., lemmings (*Dicrostonyx*), arctic ground squirrels (*Spermophilus parryi*), tundra muskoxen (*O. moschatus*) and caribou (*Rangifer tarandus*)] occupied a tundra-steppe-like zone south of the North American ice sheets until, like the Muirkirk Mammoth, they became extinct there toward the close of the Wisconsinan glaciation.

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